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PRIMARY CRYSTALLIZATION OF MINERALS AND STRUCTURE OF METEORITE CHONDRULES

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MINERALOGY

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PRIMARY CRYSTALLIZATION OF MINERALS AND THE STRUCTURES OF METEORITE CHONDRULES

Specific chondrules for the most prevalent type of meteorites (chondrites of small sphere-shaped bodies) are composed in the great majority of cases of olivine or bronzite with a certain amount of glass. In scientific literature there are enumerated very different structures composed of minerals in the chondrules. The interpretation of the processes of formation of chondrite minerals and structures is an immediate task of the science of cosmic mineralogy.(1) This task must be solved in order to explain the genesis of meteorites.(2)

The structures of the chondrules are determined by the combination of phenomena of the primary (initial) crystallization of minerals, their deformation and subsequent recrystallization.

The structures of the initial crystallization of the minerals in the chondrules observed in the polished sections by means of a microscope during all of their different forms relate to one of three categories: excentric-radiating, grid-shaped and porphyritic. It is important to note that different structures are observed in the polished sections simultaneously in adjacent chondrules. The relationship between the structures observed in the polished sections has not as yet been established to the full extent.

The process of crystallization in the chondrules is interpreted by studying the ontogeny of the minerals.(3) It has been proved that this process responds

to one of the cases of spherulitic growth and namely when the spherulite is formed by means of the splitting up of the crystal during the time of growth as a result of thermal tension or the heterometry of the crystal lattice.[3, 4] Evidence of this phenomenon is given by the presence of cone-like formations of the minerals in the chondrules, for instance in the olivine meteorite of Demin in the USSR [5] and in the pyroxene meteorite of Selma, U.S.A.[6] Both the spherulitic formations as well as the cone-like formations always grow from the point on the inner surface of the chondrule and spread out along its entire extent.

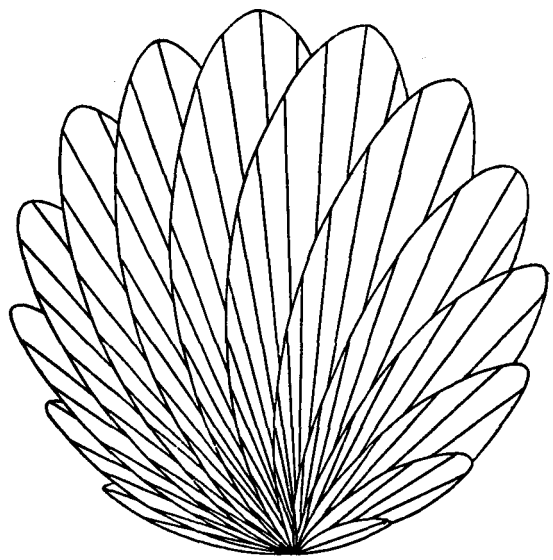

Figure 1. Diagram of the structure of a plate-like (lamellar) and needle-shaped forms of excentric-radiating spherulites.

An excentric spherulite is obtained during this crystallization in the sphere-shaped chondrule (Figure 1, idealized). The olivine, to which a plate-like appearance is characteristic, forms in this case a spherulite in the form of a diverging fagot similar to a book with opened pages (Figure 1, the circles); pyroxene, because of the needle-shaped appearance peculiar to the mineral, gives a spherulite in the form of a diverging cluster or similar to a sea urchin in form (Figure 1, straight lines). It should be noted that sometimes olivine gives rise to a needle-shaped crystallization and pyroxene gives rise to a plate-shaped

crystallization. In Figure 1 are shown the plates and needles as they gradually separate, but in nature minerals can spread out laterally up to the time they meet one another with the filling in of the entire extent of the chondrule; the spherulites which correspond to this pattern are referred to as open, and secondary spherulites are referred to as closed.

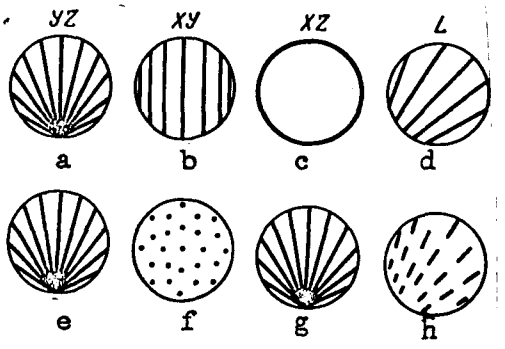

Figure 2. Diagrams of the designs (patterns) in cross-sections of spherulites along planes YZ, XY, XZ and from the obliques towards all of the axes of the angle, a to d are the plate-shaped spherulite, e to h are the needle-shaped spherulite.

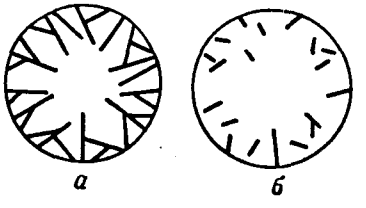

Figure 3. Diagram of a centripetal-radiating crystallization. a is a flat model, b is a volume model.

A comparison of the various structures in the chondrules which are seen in the polished sections shows that their dissimilar pattern corresponds to the various cross-sections of similar spherulites, either plate-shaped or needle-shaped. It is convenient to carry out the characteristic of the cross-sections as regards the rectangular coordinates the beginning of which is located in the center of the chondrule.

The sections of the plate-like (lamellar) spherulite (Fig. 2 a-d) have designs: in plane YZ, excentric-radiating design, in plane XY, a grid-like design; in plane XZ the section passes along one plate of mineral and the chondrule appears to be monocrystalline in the polished section. During the rotation of the

plane of the section around Z the excentric-radiating pattern is maintained, around Y the grid-like pattern shifts to a radial-radiating pattern with the center outside of the chondrule, around X the pattern remains grid-like. The slants towards all of the axes of the section take on a radial-radiating pattern with the center outside of the chondrule.

The sections of the needle-shaped spherulite (Fig. 2 e-h) develop patterns: in plains YZ and XZ, excentric-radiating patterns, and in plane XY a porphyritic pattern in the case of open spherulites and a planar pattern in the case of closed spherulites. During rotation of the plane of the section around Z there remains an excentric-radiating pattern; in the case of rotation around Y, X and in the oblique angles towards all of the axes of the sections the patterns become porphyritic in open spherulites and planar in closed spherulites with a somewhat radiating pattern.

Thus, in the sections of the same spherulite the patterns change completely at a different position of the sections. Therefore the various structures of the minerals observed in polished sections from the chondrites in accordance with their patterns in Figure 2 do not in any way indicate the structural and genetic differences in the chondrules. The minerals in the chondrules only form an initial structure, the structure of a plate-like or needle-like spherulite (if we do not consider other types of chondrules). The various "structures" which have been described in technical literature are not characteristic of natural bodies (chondrules) but rather of artificial preparations (polished sections).

Besides monospherulitic chondrules there are also found dispherulitic chondrules and polyspherulitic chondrules. In an analogous crystallization there are obtained in the chondrule two or more incomplete (imperfect) eccentric spherulites with plates or needles meeting at the border between the spherulites in the closed type or sprouting out mutually in the open type when there are obtained lattice patterns.

There sometimes take place in meteorites other processes of crystallization in the formation of minerals on the inner surface of the chondrule in a different orientation and normal growth without splitting up. In such a case the crystals reach one another, a geometric separation occurs between them and a centripetal-radial spherulite is formed (Figure 3). This type of structure of a chondrule has been described for the Saratov meteorite in the U.S.S.R.(5)

Complications in the structure of chondrules are also caused by variations from the sphere-shaped form and by contact with other minerals.

Chondrules with the structure of the initial crystallization of the minerals often undergo deformation to the point of breaking down. As a result of the large specific surface area of fine plate-like and needle-like crystals and therefore the large specific surface energy of the substance in the spherulites, the minerals of the chondrules are exposed to the processes of recrystallization by way of the splitting up into parts, consolidation of the granules and the collecting recrystallization, as in the case of spherulites of earth origin.(3,4) Still other processes of chondrule metamorphosis occur in meteorites.(7)

The next task in the study of the ontogeny of minerals in chondrites should be regarded as the clarification of the crystallographic laws of the splitting up of different minerals under various conditions.

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